Digital Applications in Archaeology and Cultural Heritage 3 (2016) 91–97

Contents lists available at ScienceDirect

Digital Applications in Archaeology and Cultural Heritage

journal homepage: www.elsevier.com/locate/daach

The value of energetic analysis in architecture as an example for data sharing

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ARTICLE INFO

Article history:
Received 18 January 2016
Received in revised form
22 June 2016
Accepted 1 July 2016
Available online 2 July 2016

Keywords:
Chaîne Opératoire
Energetics
Kenan Tepe
Mozan
Open Context
Poggio Civitate
Urkesh

ABSTRACT

The process of construction of an ancient building can be broken down into a series of steps, and analysed using tools such as the *chaîne opératoire*. This methodology permits one to explore the process, allowing for its disarticulation and a more complete understanding. It cannot, however, explore the temporal, material or energetic 'cost' of these steps. One can derive sets of cost-calculation-algorithms which can be applied to ancient architecture through 3D models which define the volumes of built material.

Such analyses can be applied to structures in any pre-industrial society, and, because of their nature, cross-cultural comparisons can be as meaningful as intra-cultural studies. Open-Context enables such studies by providing access to data needed for energetic analysis. Linking data in Open Context with cost-calculation-algorithms allows greater reproducibility, while modular cost-calculation-algorithms enable the exploration of diverse choices. By making these cost-calculation algorithms open-source, we make parameters explicit, contestable, and reusable.

1. Introduction

Architecture, as uncovered in the archaeological record, can be studied with the aim of understanding the energy needed for its construction. By understanding the steps of construction through a *chaîne opératoire*, one can break down the process of construction, defining and describing each step. Drawing on diverse sources, such as ethnographic materials, experimental archaeology, and ancient texts, we can build algorithms (computational models) to quantify the amount of energy needed in these steps. We can then visualize this with a 3D model that provides the precise volumetric dimensions of the constructed space (uncovered and reconstructed), differentiated by construction material. In this paper, we first discuss a study that used this approach to determine mudbrick production for the AP Palace at Tell Mozan, ancient Urkesh. To highlight the potential of this method, we then apply it to two other architectural datasets published in Open Context. Open Context datasets were ideal for this study because Open Context provides not only access to a wide range of datasets, but also an articulation to these datasets which allows for specific search parameters. Additionally, the use of persistent URIs for each element in the dataset allows other authors to cite these specific records, documents, and media items.

The methodology applied to the AP Palace can then be applied to other sites published in Open Context, such as Kenan Tepe or Poggio Civitate. The results not only aid in understanding the methodology, but also raise new questions.

2. Energetics in architecture – a definition of method

The study of architecture through energetics can be defined as the analysis of the construction of a building through the energy needed for the procurement, transportation, adaptation, and emplacement of the raw materials used in the construction (Abrams, 1994: 2). Thus, the energy can be calculated on the basis of work done (on an hourly basis) by one or more people involved in each of those steps. As a basic example, a stone foundation requires quarry workers who mine and finish stone, transportation to the

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http://dx.doi.org/10.1016/j.daach.2016.07.001
2212-0548/© 2016 Published by Elsevier Ltd.

construction site, and workers to cut the foundation trench and place the stone. At the basis of such an analysis three types of data are needed: a *chaîne opératoire* which attempts to define the steps taken, a set of ‘algorithms’ which define the hours needed for the tasks involved, and a quantification of the volumes of the ancient construction.

The *chaîne opératoire* is a method of analysis which focuses on the individual steps taken during the production of an object; the method was initially developed for lithic analysis, but it has been adapted here to describe the steps taken in the construction of architecture. The *chaîne opératoire* unpacks a generic ‘moment of construction’ into a series of discrete steps, including the procurement of all of the raw materials needed, their use in the manufacture of building elements, the transportation involved as well as their placement in the structure itself. While no numeric values are generated, a series of questions regarding such a construction arise: where is the nearest source of stone? Could streams have been used in the transportation of materials? And what effect might the workspace needed for mudbrick construction have had on local agriculture? Such questions help clarify the practical dimension of the construction process, and can aid in the definition of the choices made in the design of a particular building. Furthermore, the *chaîne opératoire* helps formulate a timeline for the construction process: mudbricks could only be made in certain periods of the year, for example.

The *chaîne opératoire* method as applied in this paper focuses exclusively on the technical aspects of construction rather than additionally exploring the social framework (or ‘total social phenomenon’ in Mauss' terms) in which this process develops. In fact, definitions of the *chaîne opératoire* vary (Martinón-Torres, 2002) from the narrowest technical “Leroi-Gourhan defined this as the series of technological operations which transforms a raw material into a usable product” (Cresswell, 1990: 46) to the widest cognitive “integrated webs weaving skill, knowledge, dexterity, values, functional needs and goals, attitudes, traditions, power relations, material constraints, and end-products together with the agency, artifice, and social relations of technicians” (Dobres, 1999: 128). While it is true that a technical analysis tends to exclude the social aspects, at least initially, the case can also be made that only after a detailed understanding of the technical side can even some of the social questions be considered.

The study of energetics of construction also requires modelling theb ‘algorithms’ of construction. These aim to quantify one or more variables in a specific activity. This variable can be materials used in the process, materials produced in the process, workforce needed and/or the time needed to complete a task. The sources for these algorithms can be placed in three categories: ethnographic observation, experimental archaeology, and textual sources.

Ethnographic observations include research done by scholars (primarily anthropologists) looking at modern work situations. These observations establish a relationship between the variables being considered (materials used, end product, workforce required and the time needed for tasks) that are common to the culture in which they are working, and come from a wide range of geographic regions and chronological periods. It should be noted that what is being drawn from these studies is not related to actor intentionality as would be the case with a thick description (Geertz, 1973: 13–16), but rather the sequence of operations being performed as described in the ‘unpacking’ of the *chaîne opératoire*, and variables relating to those operations. These are clearly influenced by a large number of factors including those relating to the actors involved, but intentionality does not play a role when considering the technical aspects of the *chaîne opératoire*, as we do here.

The second category of sources, those deriving from experimental archaeology, is similar to ethnographic observations but for one aspect: the process being studied is not part of the activities normally carried out, but rather attempts to re-create elements of material culture found in the archaeological record. The distinction is important, as the data derived from experimental archaeology is based on the archaeologist's re-creation of an otherwise undocumented process. This re-creation is normally derived from information obtained from local informants (who may know and work with the materials already) as well as research done by other scholars.

The third group of algorithms comes from textual sources. These are normally ancient administrative texts which describe specific processes. From these texts we can derive algorithms that include the variables under consideration for a specific process: materials used, end product, workforce required and time needed.

The specific algorithms derived from these three sources form a guide which can be used in the study of energetics rather than a set of fixed rules, since the conditions, materials, skills, working conditions, psychological considerations and physical characteristics of the workforce all influence the variables under consideration. Ideally, the same algorithm would be derived from all three sources, as a way to understand the impact of these secondary influences; however, the ancient situation may have been impacted by these influences in ways which are incalculable today. A consideration of the use of these sources to generate algorithms, and their validity as applied to the archaeological record, is beyond the scope of this paper, but has been treated elsewhere (Buccellati, forthcoming).

The third and last type of data when considering the energetics of construction is a quantification of the constructed volume in the archaeological record, in order to apply the algorithms to a specific edifice. 3D models are becoming more and more ubiquitous in archaeological projects, and the perform a wide variety of functions, from communication to planning of future excavation areas (see Buccellati (2015) for further discussion of 3D models and their use in archaeological fieldwork). One oft-overlooked (in archaeology) function of 3D modelling software is the ability to calculate, with great precision, the volume of the individual blocks used in the model. This is fundamental for the analysis of energetics, as the quantity of specific construction elements can be queried from such a model, and the algorithms described above can be applied to a specific edifice. It is important, however, that the 3D model be a model of the archaeological record, and not a possible reconstruction of the building. It is also important that the model differentiate, using solid blocks, between the diverse materials used in the construction, so as to derive the volumes of specific materials used.

Thus the *chaîne opératoire* provides an understanding of the process of construction in its diverse facets; the algorithms provide a general guide to calculating the materials used, end product, workforce required, and time needed for the various tasks; and the 3D model provides the specific volumes of constructed space which are the input needed in the algorithms to estimate the ‘cost’ in terms of time, workforce and materials of a specific building.

An in depth study of this method as well as the results of its application to the AP Palace at Tell Mozan, ancient Urkesh are to be published in a forthcoming monograph entitled Three-Dimensional Volumetric Analysis in an Archaeological Context: The Palace of Tupkish at Urkesh and its Representation (Buccellati, forthcoming). This royal palace, built in the latter half of the third millennium BC during the Akkadian Period, is a prime example of monumental architecture. The aim of this paper is to show how comparative data from Open Context can aid the research goals through the availability of comparative material and potential for larger scale comparative analyses.